THE WEATHER AND CIRCULATION OF JULY 1960

Persistent Heat in the Pacific Northwest

RAYMOND A. GREEN

Extended Forecast Section, U.S. Weather Bureau, Washington, D.C.

1. HIGHLIGHTS

July 1960 was especially noteworthy for prolonged, excessive heat in the Pacific Northwest. The greatest departures of average temperature from normal, more than 6° F., were centered on the Oregon-Idaho boundary (fig. 1). New temperature records at Boise, Idaho included an all-time high of 111° F. on the 19th, 27 days with 90° or higher, 11 days with 100° or higher, and the highest monthly average in 62 years. New records at other stations appear in table 1. Sustained high temperatures, low humidity, and little precipitation brought, in the words of LaMois of the U.S. Forest Service [1] ". . . extremely critical burning conditions throughout the Western States during July. More than 4,000 fires occurred, most of which started from heavy concentrations of lightning storms which struck California, Oregon, Washington, Montana, and Idaho . . . . The fire fighting bill during July alone was more than $15 million."

Abnormal warmth over the western half of the United States was accompanied by unseasonable coolness over much of the eastern half, with greatest departures in a band from northern Texas to eastern Pennsylvania (fig. 1). New low averages for July were also numerous. Cleveland, Ohio headed the list (table 1) with an average temperature of 67.6° F. and a departure from normal of −6.1° F.

TABLE 1.—*New record average temperatures for July, and their departures from normal, observed in 1960*

	Monthly average (° F.)	Departure from normal (° F.)
	High temperature	
Boise, Idaho	80.7	+5.9
Nome, Alaska	54.3	+4.7
Salt Lake City, Utah	81.2	+4.6
Pendleton, Oreg	78.3	+3.8
Idaho Falls, Idaho	71.8	+2.6
Miami, Fla	83.7	+1.1
	Low temperature	
Cleveland, Ohio	67.6	−6.1
Youngstown, Ohio	67.9	−3.7
Pittsburgh, Pa	68.6	−3.7
Philadelphia, Pa	*73.2	−3.1
Wilmington, Del	**73.1	−2.8

*Equaled in 1895.
**Equaled in 1894.

Tropical storm Brenda moved up the east coast the last few days of the month. It caused little wind damage, but heavy rains were reported along its path.

2. MEAN CIRCULATION

From June to July high-latitude blocking diminished over northern Canada and increased over the Siberian Peninsula (+260 feet, fig. 2). During July two 5-day mean blocking ridges coalesced with the subtropical ridge in the Pacific, and amplification of the circulation occurred downstream at middle latitudes. Height anomalies in the troughs and ridges of figure 2 were generally larger than their June counterparts, and a new mean wave was introduced into the pattern in the eastern Atlantic. Further evidence of large amplitudes in July is given by the displacement of the principal axis of maximum mean 700-mb. winds. In figure 3 it can be seen that in mean troughs of the western part of the hemisphere southward displacement of the "jet stream" occurred, while in the ridges the displacement was northward except in the central Pacific.

The slow-down of the temperate westerlies was not as great as one expects to observe with amplification of this magnitude. A drop of only 0.2 m.p.s. from the preceding

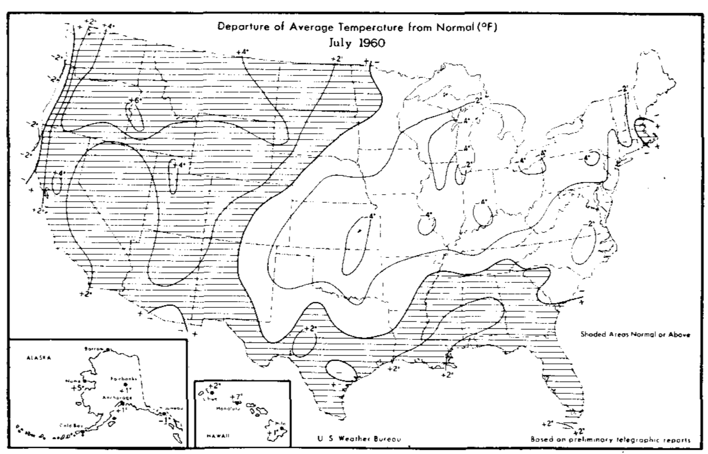

FIGURE 1.—Departure of average temperature from normal (°F.) for July 1960. Noteworthy features include abnormal warmth in the Northwest and coolness from the Central Plains northeastward. (From [2].)

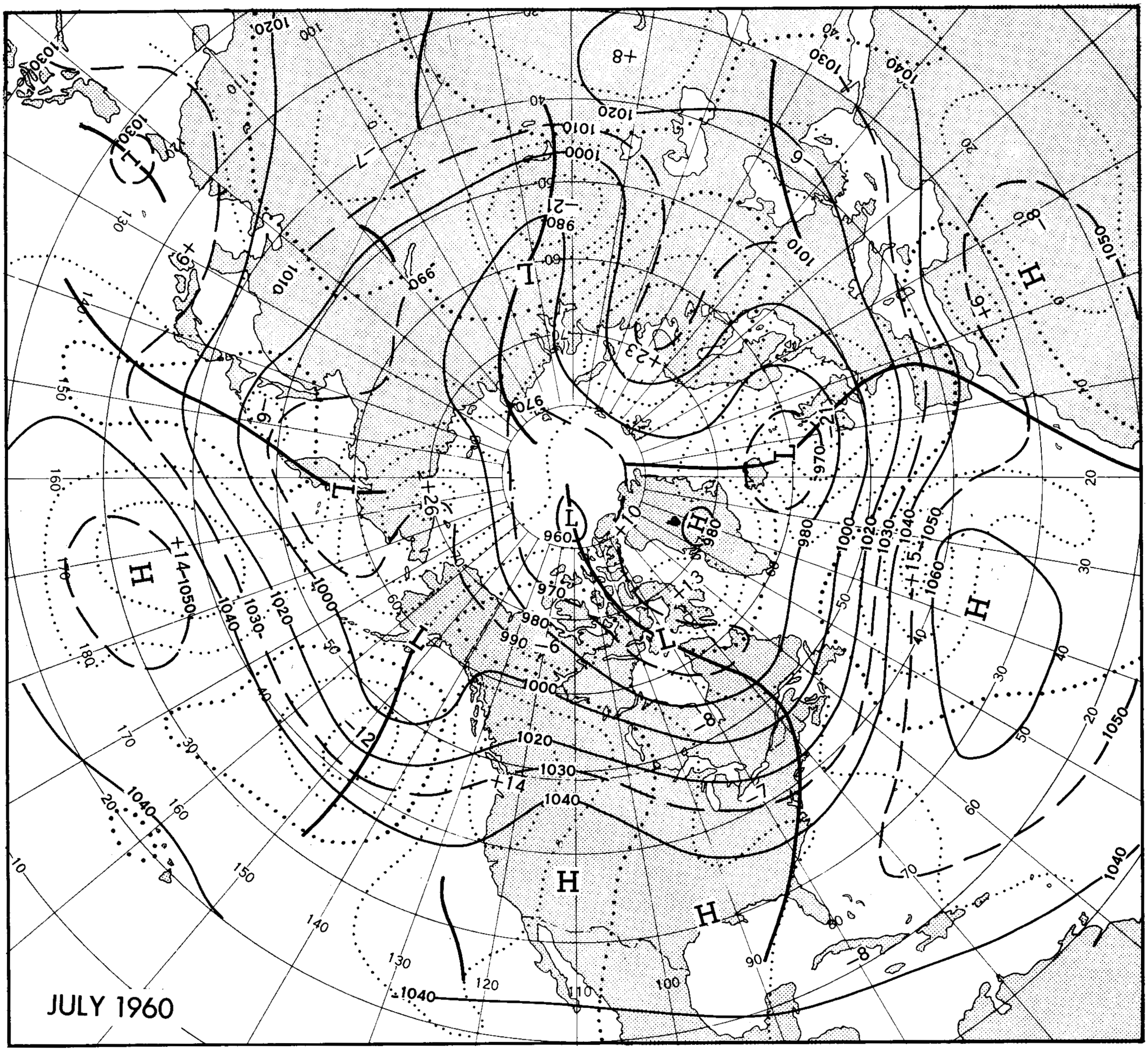

FIGURE 2.—Mean 700-mb. contours (solid) and height departures from normal (dotted), both in tens of feet, for July 1960. Greater than normal amplitude of mean troughs and ridges in temperate latitudes is suggested by departure from normal pattern.

month took place in the departure from normal of the mean monthly 700-mb. zonal index for the western half of the Northern Hemisphere. Five-day mean indices of the temperate westerlies completed a minor oscillation about the normal by mid-July and remained above normal thereafter.

Large negative changes of mean 700-mb. height anomaly from June to July, shown in figure 4, indicated strong deepening over the eastern Pacific and the British Isles at temperate latitudes, while falls over northern Canada and rises over the Asian sector of the Arctic Basin attended the migration of blocking at high latitudes. Over western Canada, rises reflected the growth of the mean ridge which strongly influenced the temperature pattern of the United States.

3. TEMPERATURE

The mean ridge at 700 mb. over the Pacific Northwest was both stronger than normal and persistent. Five-day mean height anomalies there remained well above normal the entire month. Not once did the weekly average temperature fall below normal at reporting stations in Idaho

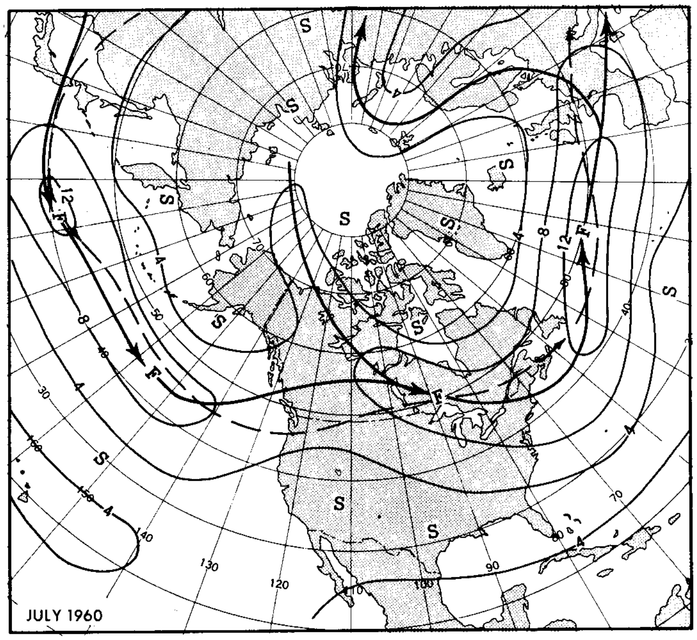

FIGURE 3.—Mean 700-mb. isotachs (in meters per second) for July 1960. Solid arrows indicate axes of west wind maxima, dashed arrows the normal for the month. Eastward from the central Pacific the primary axis was displaced southward from normal in mean troughs and northward from normal in ridges.

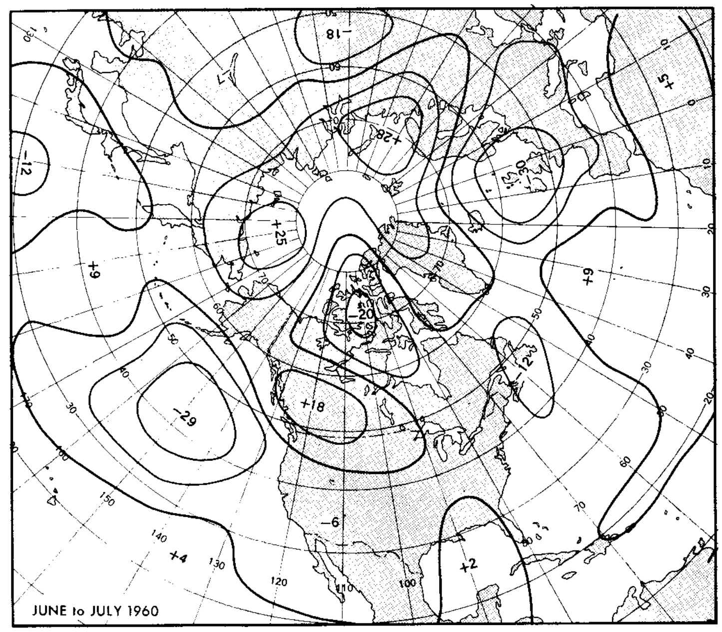

FIGURE 4.—Difference between monthly mean 700-mb. height anomaly for June and July 1960 (July minus June) in tens of feet. Pronounced deepening occurred in the northeastern sections of the Pacific and the Atlantic. Large changes at polar latitudes accompanied the migration of blocking from northern Canada.

and inland sections of Oregon and Washington [2], and the same was true in Montana after the week ending July 3. Thus the extent and intensity of warm temperature anomalies were largely products of persistence.

One locally effective warming factor was the downslope flow indicated by the departures from normal of mean 700-mb. height in figure 2. The flow was generally northeasterly where centers of maximum departure were observed in valleys of Idaho, Utah, and California which lie southwestward from extensive mountain barriers. Perhaps of greater importance was the fact that more than 80 percent of possible sunshine was realized at most stations in the anticyclonic environment of the Northwest.

Over the remainder of the Nation there was more intramonthly variability of the anomalies of both temperature and 700-mb. height. Even so, temperatures averaged at least slightly less than normal each week in Pennsylvania and sections of Ohio and New York adjacent to Lakes Erie and Ontario. Scattered stations westward as far as the Central Plains also reported subnormal averages for every week of the month [2].

Most of July's area of below-normal temperature was also in the below category in the mean patterns for spring and for June [3]. Exceptions were a semicircular region from southeastern Colorado to central Texas and Atlantic Coastal States northward from Virginia. In general the cool temperatures of July were what might be anticipated from the mean height anomaly field and the cyclonic northwesterly flow in figure 2. In addition, the large amplitude of the mean circulation supported a southward displacement from normal of the tracks of daily Highs and Lows (fig. 5). One branch of the paths of both dipped abnormally far into the United States, augmenting the southward penetration of cool Canadian air.

Cooling over the Soushwest from the extreme heat of June left that section of the country only slightly above normal in July. A similar change took place in the Northeast. Changes of the temperature anomalies from June to July followed rather closely the changes of 700-mb. height anomaly in figure 4. Thus general cooling occurred along a diagonal band oriented southwest to northeast, and general warming over the Northwest and the Southeast. Among 100 selected stations the largest change was only 2 classes, qualitatively indicative of more than usual month-to-month persistence. This is quantitatively verified by the fact that 76 of the stations appeared in the 0- or 1-class change category, while Namias found June to July persistence of these classes 72 percent on the average from 1942 to 1954 [4].

4. TROPICAL STORM BRENDA AND PRECIPITATION

Brenda formed in the eastern Gulf of Mexico in late July. The behavior of the mean circulation prior to and during the storm's short life is depicted in the series of overlapping 5-day mean 700-mb. maps in figure 6. On the chart for July 21–25 (A) a deep mean trough extended along the Atlantic coast well into the Tropics from Labrador. By July 23–27 (B) the trough had sheared, and

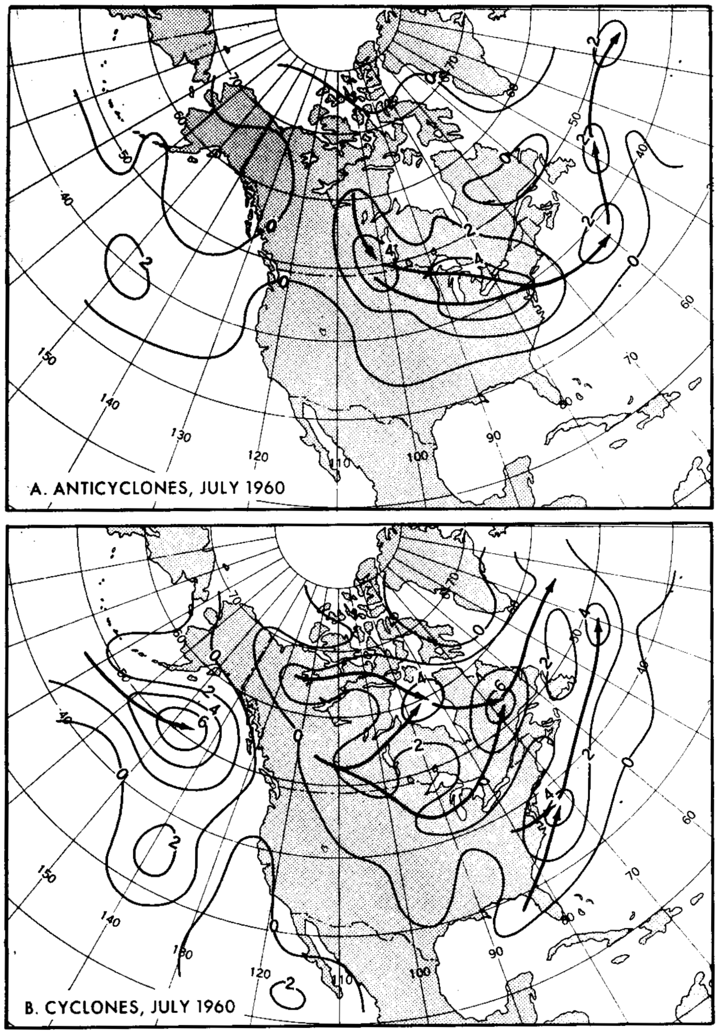

FIGURE 5.—Number of (A) anticyclone passages and (B) cyclone passages within quadrilaterals of 66,000 square nautical miles during July 1960. Primary tracks are indicated by solid arrows. Branches of the tracks of both anticyclones and cyclones pushed abnormally far southward into United States. Note the scarcity of migrating systems west of the Continental Divide.

the tropical portion retrograded to Florida, while the northern portion of a similarly sheared trough advanced from Oklahoma to Indiana. By July 26–30 (C) the fractured parts of the troughs were joined with the Hudson Bay Low to form a deep mean trough across the Great Lakes and the eastern Gulf of Mexico. Brenda formed in this trough.

The subsequent path of the storm coincided rather closely with the 30-day mean trough line of figure 2. This tendency for storms to move along mean troughs has been discussed by Klein [5], who listed numerous examples from previous years. With such coincidence the question of cause and effect often arises, since it may be argued that low pressures in the storm largely determine the location of the trough. For example, see the

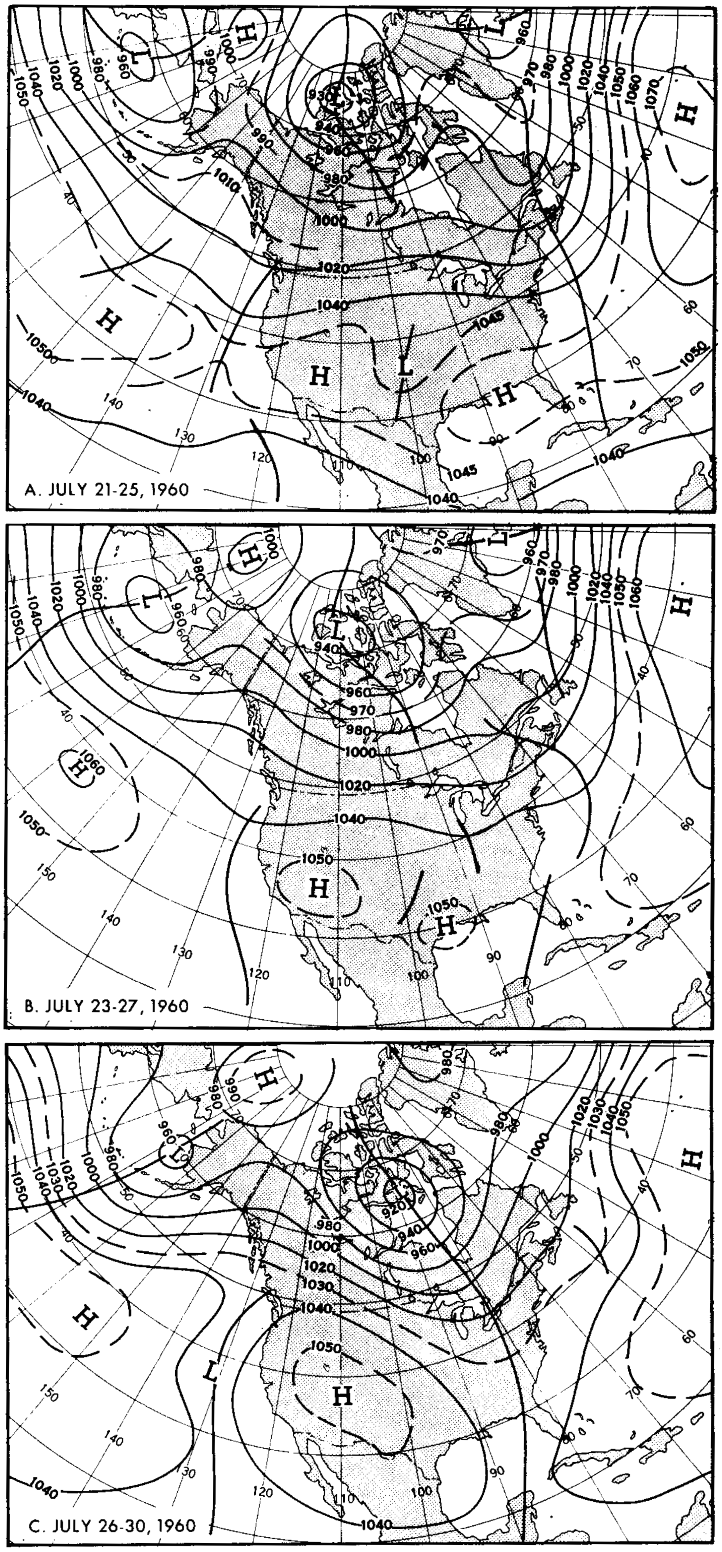

FIGURE 6.—Five-day mean 700-mb. contours in tens of feet for (A) July 21–25, (B) July 23–27, and (C) July 26–30, 1960. Tropical portion of mean trough in the western Atlantic (A) retrograded to Florida (B) and joined with sheared portion over western Indiana to form deep trough through eastern Gulf of Mexico (C) where tropical storm Brenda developed. Heavy rains occurred on July 23 and 24 near the mean Low over Oklahoma (see A).

TABLE 2.—*Selected precipitation totals (inches) for July including totals during close proximity of Brenda*

	Total for July	Total during Brenda
Tampa, Fla.	*20.59	16.36
Orlando, Fla.	*19.57	10.79
Jacksonville, Fla.	*16.21	1.57
Savannah, Ga.	*15.70	2.89
Ft. Myers, Fla.	13.76	4.42
Charleston, S.C.	11.74	4.43
New York, N.Y.	*9.97	4.90
Bridgeport, Conn.	8.13	3.57
Richmond, Va.	7.34	2.39
Wilmington, Del.	6.18	2.51

*New record for July.

correspondence between Ramage and Ballenzweig in a recent issue of the *Journal of Meteorology* [6]. To throw some light on this question, a mean map of the 25 July days preceding Brenda was constructed (fig. 7). The storm path superimposed on this pattern follows the mean trough line rather well. Obviously in this case the low pressures of the storm altered the mean 30-day trough position very little.

The storm's effect on the precipitation pattern (fig. 8), however, was more substantial. Rainfall totals from Brenda comprised a large proportion of the monthly amount at a number of stations, as revealed by table 2, where both totals are tabulated for comparison. At Tampa, Fla., more than three-fourths of the monthly accumulation could be attributed to the storm. In general, much higher proportions of the monthly amounts were caused by the storm near the area of its formation than elsewhere along the path where rapid motion occurred. During Brenda's passage new records for 24-hour rainfall were established at Orlando and Tampa, Fla., and at New York City.

Most of the precipitation in the Great Lakes Region is attributable to frontal Lows traversing the southward displaced storm track of figure 5B. An additional feature of interest associated with the first of these Lows was the outbreak of tornadoes in North Dakota on July 2 and in Indiana on the 3d. Other tornadoes were reported later in the month, mostly after the 20th, and were most frequent from the Southern Plains to Iowa. Only those in Iowa were clearly associated with frontal troughs, while the remainder occurred beneath cyclonic upper flow in maritime tropical air.

Rainfall was more than twice the normal from the Texas Panhandle to Arkansas, where moisture was in adequate supply in the weak flow from the Gulf of Mexico around the mean High centered over eastern Texas (fig. 2). Some of this precipitation was frontal in nature, but the heaviest, in eastern Oklahoma and western Arkansas, was triggered by a trough which formed during a readjustment of mean waves. When the wavelength downstream from the retrograding Pacific trough became long, new mean troughs appeared on the 5-day mean map for July 19–23 (not shown) along the west coast and over Oklahoma. Both are shown in the mean circulation of figure 6A for

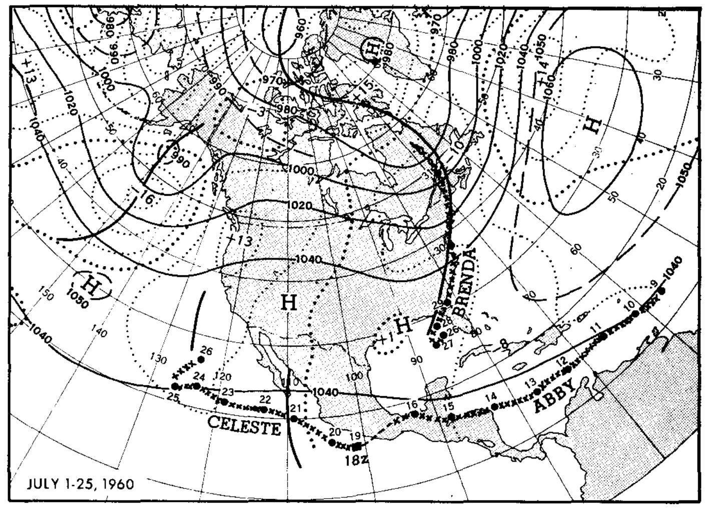

FIGURE 7.—Mean 700-mb. contours (solid) and height departures from normal (dotted), both in tens of feet for July 1–25, 1960. This represents the mean circulation prior to the formation of tropical storm Brenda (dotted track, east coast) which traveled up the mean trough (heavy vertical line). Also depicted are paths of hurricanes Abby and Celeste. Large dots indicate 1200 GMT positions of storms, and numbers the July date of each position.

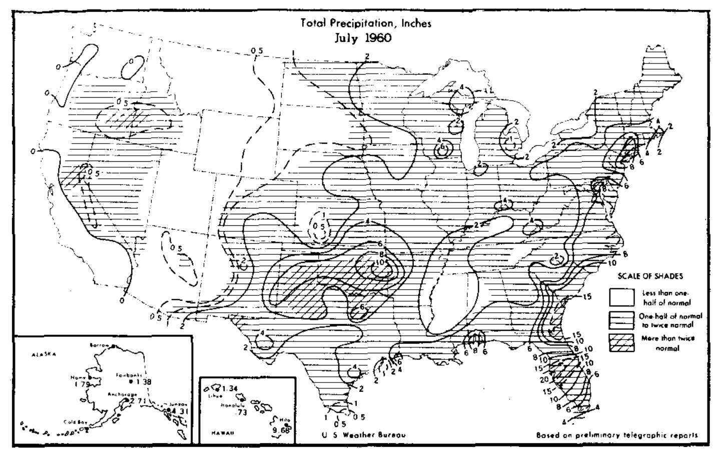

FIGURE 8.—Total precipitation (inches) for July 1960. Record monthly amounts for July were observed along the east coast. (From [2].)

July 21–25. The Oklahoma trough was the stronger of the two, and heavy rain occurred in its vicinity during the 23d and 24th. Subsequently a portion of this trough advanced to join the mean trough in which Brenda was spawned, while the trough near the west coast strengthened and advanced enough to bring showers and local temporary relief from critical burning conditions in forested areas of the Far West.

Practically no rain had fallen over the western tier of States until this time. Dry weather also prevailed over adjoining States and from Montana to Arizona (see fig. 8), where the general accumulation was less than half an inch. Sheridan, Wyo., had 3.51 inches during the period from January to July, the driest like period ever recorded; and

Phoenix, Ariz., reported no measurable rain for 143 consecutive days ending July 23. The dryness was a natural consequence of the persistent anticyclonic circulation over western United States. Migratory cyclones were completely absent from the area west of the Continental Divide (fig. 5B). In addition, orographic precipitation was far below normal in the Pacific Northwest where the mean "jet" was diverted far to the north (fig. 3).

5. OTHER STORMS IN THE TROPICS

Hurricane Abby was discovered near the Windward Islands. It reached hurricane intensity on the 10th, traveled steadily westward near 15° N. latitude, and skirted the northern coast of Honduras during the 14th. After moving inland on the 15th, the storm apparently dissipated and dropped from sight. On the basis of continuity, however, it is likely that remnants of the storm were instrumental in the formation of hurricane Celeste on the 19th (see dashed continuation of Abby, fig. 7). Celeste moved west-northwestward well off the coast of Mexico, turned westward south of Baja California, on the 22d, weakened to a tropical storm the following day, and dissipated thereafter.

In the western Pacific two storms attained typhoon intensity. Typhoon Polly formed east of Luzon, P.I., on July 19 and took a slow northerly track through the East China Sea and the Yellow Sea, reaching the coast of Manchuria on the 29th. Shirley also formed east of the Philippines, but took a more westerly course and struck Formosa on the last day of the month.

REFERENCES

1. L. M. LaMois, "Weather and Forest Fires," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVII, No. 33, August 15, 1960, p. 7.
2. U.S. Weather Bureau, *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVII, Nos. 27–31, July 4, 11, 18, 24, August 1, 1960.
3. C. M. Woffinden, "The Weather and Circulation of June, 1960—A Hot Dry Month in the Southwest," *Monthly Weather Review*, vol. 88, No. 6, June 1960, pp. 229–234.
4. J. Namias, "The Annual Course of Month-to-Month Persistence in Climatic Anomalies," *Bulletin of the American Meteorological Society*, vol. 33, No. 7, Sept. 1952, pp. 279–285 (and an unpublished extension through 1954).
5. W. H. Klein, "The Weather and Circulation of June 1957—Including an Analysis of Hurricane Audrey in Relation to the Mean Circulation," *Monthly Weather Review*, vol. 85, No. 6, June 1957, pp. 208–220.
6. C. S. Ramage, "Long-Period Circulation Anomalies and Tropical Storms," *Journal of Meteorology*, vol. 17, No. 3, June 1960, p. 375, and Reply by E. M. Ballenzweig, pp. 375–376.

Publications by Weather Bureau Authors

J. K. Angell, "An Analysis of Operational 300 Mb. Transosonde Flights from Japan in 1957–58," *Journal of Meteorology*, vol. 17, No. 1, Feb. 1960, pp. 20–35.

K. Butson, "Florida Winter Weather: 1957–58," *Weatherwise*, vol. 11, No. 2, Apr. 1958, pp. 58–59.

N. L. Canfield, "Review of *Atlas of 300-mb. Wind Characteristics for the Northern Hemisphere*, by Lahey et al., Univ. of Wisconsin Press, Madison, 1960," *Bulletin of the American Meteorological Society*, vol. 41, No. 7, July 1960, p. 399.

C. B. Carney, "Freeze Damage to Plants," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 21, May 25, 1959, pp. 7–8.

G. P. Cressman, "Hemispheric Nondivergent Barotropic Forecasting," *The Atmosphere and the Sea in Motion*, Scientific Contributions to the Rossby Memorial Volume, Bert Bolin, Ed., The Rockefeller Institute Press in association with Oxford University Press, New York, 1959, pp. 475–485.

R. A. Dightman, "An Application of Climatology to Alfalfa Harvesting," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 28, July 13, 1959, p. 8.

S. Fritz, "Satellite Meteorology," in "United States National Report 1957–1960 Twelfth General Assembly, International Union of Geodesy and Geophysics," *Transactions of the American Geophysical Union*, vol. 41, No. 2, June 1960, pp. 217–220.

J. G. Georg, "Cranberry Crop and Weather in Wisconsin, 1959," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 41, Oct. 12, 1959, pp. 7–8.

D. L. Harris, "Storm Surges," in "United States National Report 1957–1960, Twelfth General Assembly International Union of Geodesy and Geophysics," *Transactions of the American Geophysical Union*, vol. 41, No. 2, June 1960, pp. 266–269.

H. E. Landsberg, "Do Tropical Storms Play a Role in the Water Balance of the Northern Hemisphere?" *Journal of Geophysical Research*, vol. 41, No. 4, Apr. 1960, pp. 1305–1307.

H. E. Landsberg, "Review of *General Climatology*, by H. J. Critchfield, Prentice-Hall, Englewood Cliffs, N.J., 1960," *Science*, vol. 131, No. 3417, 24 June 1960, p. 1882.

A. R. Long, "Dry Weather in Alabama, October 1958–August 1959," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 35, Aug. 31, 1959, p. 8.

L. Machta, "Meteorological Factors and Fallout Distribution," pp. 33–56 in *Low-Level Irradiation*, Austin M. Brues, Editor, Publication No. 59 of the American Association for the Advancement of Science, Washington, D.C., 1959, 148 pp.

L. Machta and R. J. List, "The Global Pattern of Fallout," Chapter 2 (pp. 26–36) in *Fallout, A Study of Superbombs, Strontium 90 and Survival*, John M. Fowler, ed., Basic Books, Inc., New York, 1960, 235 pp.

F. Ostapoff, "Antarctic Oceanography" in "United States National Report, 1957–1960, Twelfth General Assembly International Union of Geodesy and Geophysics," *Transactions American Geophysical Union*, vol. 41, No. 2, June 1960, pp. 257–258.

J. C. Purvis, "Weather and Peaches in South Carolina," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 2, Jan. 12, 1959, pp. 6–8.

A. D. Robb, "Rose Culture and the Weather," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVII, No. 2, Jan. 11, 1960, p. 8.

L. H. Seamon, "Weather of the Year 1958," *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 4, Jan. 26, 1959, pp. 7–8.

S. Teweles and F. G. Finger, "Reduction of Diurnal Variation in the Reported Temperatures and Heights of Stratospheric Constant-Pressure Surfaces," *Journal of Meteorology*, vol. 17, No. 2, Apr. 1960, pp. 177–194.

H. Wexler, "Satellites et Meteorologie," *Met-Mar,* Bulletin Trimestriel de Liason et d'Information, No. 28, Direction de la Meteorologie Nationale, Paris, April 1960, pp. 13–19.

U.S. GOVERNMENT PRINTING OFFICE: 1960